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Volcanic ash monitoring over Bucharest area using a multiwavelength Raman lidar

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This paper reports the results obtained during a monitoring campaign, performed over Bucharest area in order to detect the volcanic ash, released by the volcano eruption in Iceland. The lidar images showed that two volcanic ash layers entered Romania within the first eruption event. Slight traces were seen at 5 Km and another layer between 1 and 3 Km altitudes. The second episode was produced by a change in air masses trajectories and layers of ash were identified by lidar at 4 and 6 Km. Deposition processes significantly increased the ground level concentration and changed the size distribution of the particles.

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1. Introduction

Atmospheric aerosols, in any form they take as volcanic ash, Saharan dust, soot etc. have an important role in determining the Earth radiation balance [1, 2], and can also affect health and economy (for example aviation). Aerosols effects are highly dependent on the particle size and their optical properties [3]. Despite their importance in environmental and climate effects studies, the characterization of aerosols is very difficult because of their spatial distribution and time of residence in atmosphere. Nowadays, the analysis of aerosols is facilitated by lidars (light detection and ranging), which also measure trace gases, clouds and the basic atmospheric variables (temperature, wind). Lidars present several advantages like: high spatial and temporal resolution of the measurements, the possibility of observing the atmosphere at ambient conditions, the potential of covering the height range from the ground to more than 20 km altitude.

Due to their advantages, lidars were used to characterize meteorological phenomena and detect atmospheric perturbation after major volcanic eruptions, intercontinental transport of air pollution, desert dust and forest-fire smoke [4]. The recent Eyjafjallajokull volcano activity highlighted the effectiveness of Lidars in obtaining real-time data about volcanic ash layer thickness height and particle concentration and size. Although there have been numerous reports on Lidar studies during other volcanic reactions [5, 6], it is a known fact that eruptions varies between volcanoes and between eruptions stages of the same volcano [7]. Taking this into the consideration, together with economical and environmental issues, the eruption of the Eyjafjallajokull volcano has been extensively monitored by lidar stations across Europe [8, 9, 10]. Most findings for France [9], Switzerland [10], Germany [11] and so on have been published or presented in various reports. So far only minor reports have presented the volcano ash monitoring at the Bucharest lidar station [12]. This paper aims to report the results obtained during the monitoring campaign, which was performed over Bucharest area, in order to detect the volcanic ash released by the eruption in Iceland. For this study, we used a lidar system to detect the layers and height of the volcanic ash plume. We also determined the concentration of particles, which were transported to ground level through deposition processes.

2. Methodology

The Bucharest station performed measurements on 17th, 18th and 21st of April. The measurements where performed using a state of the art multiwavelenght lidar sistem. In the course of 19th and 20th of April there was an almost total cloud cover, therefore no lidar measurements could be made.

The lidar system consists of a transmitter (laser emit pulses into atmosphere) and a receiver (telescope), which collects the radiation backscattered from atmosphere constituents. The collected radiation is filtered by special optics and transformed in electric signal through photodetectors [4]. The lidar signal is proportional with the concentration of scattering particles.

Bucharest lidar station part of EARLINET (European Aerosol Research Lidar Network) uses a multiwavelength lidar system with 3 elastic, 3 Raman and depolarization channels. Detection is made both in analog and photon counting (except IR channel, only analog and water vapour channel in photo counting), therefore the dynamic range is increased up to 15Km, altitude, depending on the atmospheric transmission.

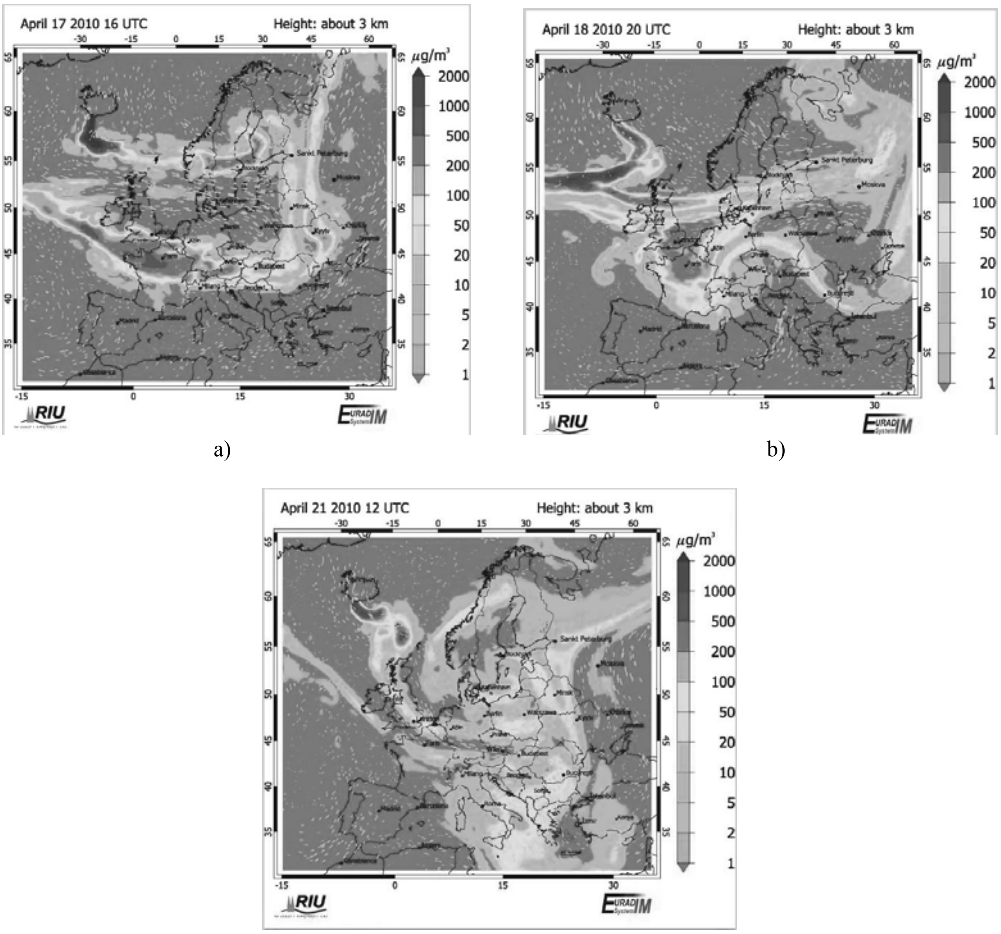
The groundbase measurements where performed using an aerodynamic particle sizer (APS) spectrometer. The APS 3321 TSI Model detects particles with sizes in the range from 0.5 to 20 μm using a sophisticated time-offlight technique that measures aerodynamic diameter, in real time. Particle concentrations were derived from APS data.

3. Results and discussion

After the eruption of the Eyjafjallajokull volcano on April 14th, volcanic ash plumes formed in the atmosphere, carrying along large amounts of eruptive material like water vapour and sulphur dioxide [13]. The plume travelled across the United Kingdom, Scandinavia and Central Europe entering the Romanian premises on April 17th. During this eruption event, the ash plume covered almost the Romanian territory and by the next day the plume was reduced to a band, which stretched from the NW to SE of the country. The dispersion model (developed by Rhenish Institute for Environmental Research from the University of Koln) showed that at 3 km, the concentrations of particles ranged from 50 to 100 μg/m^3, during 17th and 18th of April (Fig. 1 (a), (b)).

The second volcanic ash event April 21st, generated plumes which spread across the entire Romanian territory with more concentrated masses over the southern and central parts, especially over Bucharest (Fig1 (c)). During this day the dispersion model indicated the same concentration of particles as in the first days. However, the modelled data need to be validated by measured data specially using Lidar.

The lidar images reveal two volcanic ash layers within the first day following the plume entering Romania. Only small traces could be seen at 5 Km and another layer between 1 and 3 Km altitude (Fig 2 (a)). Also, clouds in formation were detected at the lowest layer. Ansmann et al. [11], Flentje et al. [13] and Balis et al. [14] reported as well, the presence of two layers at aproximately 5-6 Km and 2.5 Km. Depolarizing particles are visible on the night of April 17, but the layers became more clearly defined on April 18. The depolarisation ratio is about 0.30 (Fig. 2 (b)), which indicates the presence of nonspherical particles. Ansmann et al. [11] obtained similar data.



a)

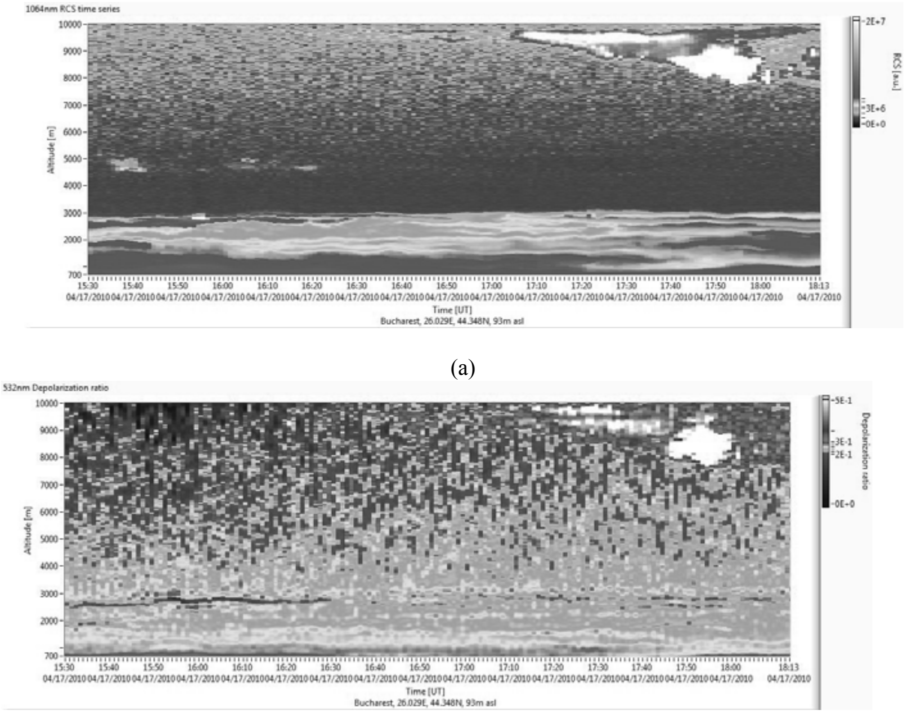
b)

(c)

Fig. 1. Dispersion model data (Rhenish Institute for Environmental Research, University of Koln) for a) 17th, b) 18th and c) 21st of April.

By the next day, the thin layer at 5 Km was not detected anymore, but the layer at 2 Km thickened and became denser (Fig. 3 (a)). The thin layer probably descended to lower altitudes and mixed with the 2 Km layer. Flentje et al. [13] observed the same descending tendency of the 5 Km layer. The depolarisation ratio can be determined from Fig. 3 (b), which indicates the same values as for April 18th and therefore the presence of ash particles.

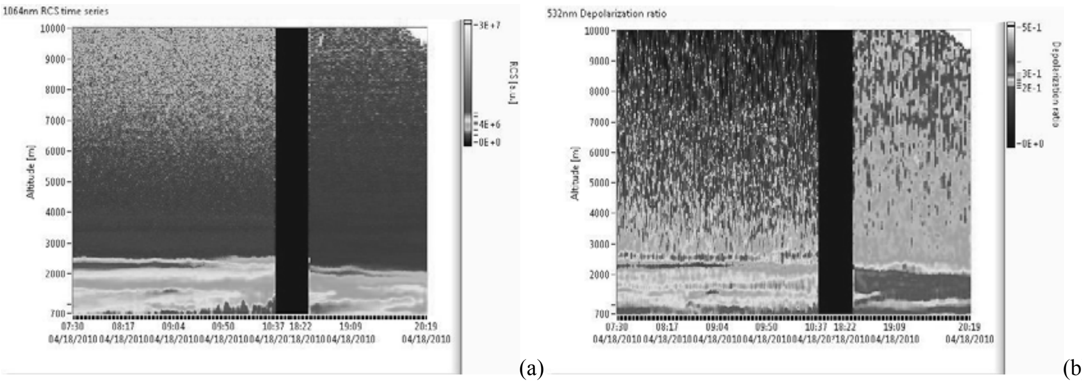
The second episode was produced by a change in air masses trajectories on April 21st. Early in the morning, layers of ash arrived at various altitudes, traveling over Western Europe (Fig. 4 (a)). Although distinct depolarizing layers were identified by lidar at 4 and 6 Km, the ash was dispersed over a large interval of altitudes and descending to PBL. Dry deposition of ash particles during the night produced an increase of the depolarization inside PBL. The depolarisation ratio, for April 21st, was slightly higher (~0.35) compared to the previous days, as shown in Fig. 4 (b).



(a)

(b)

Fig. 2. Lidar images for April 17th: a) Range Corrected Signal temporal series and b) depolarisation ratio temporal series.



(a) (b)

Fig. 3. Lidar images for April 18th: a) Range Corrected Signal temporal series and b) depolarisation ratio temporal series.

During the first event, Ansmann et al. [11] found that the maximum mass concentration was in the order of 1 mg/m^3 (± 30 %). In our study, mass particle concentrations were derived from lidar measured data using an algorithm developed by Raut et al. [15]. Values of only 65 μg/m^3, on the first day, April 17th, and higher values, 100 - 150 μg/m^3 on the second day, April 18th, were found. These values were calculated for the lowest layer, 2-3 Km. The same layer became more concentrated during the second event (April 21st), 240 μg/m^3 and clouds in formation were seen at the same level.

The data, collected from the Aerodynamic Particle Sizer, for PM10 and PM2.5 confirm the results obtained with the lidar system. That is, higher concentrations of both PM10 and PM2.5 were detected in the evening of April 21st than during the first two days. On April 17th and 18th, maximum values of 0.1 μg/m^3, for PM10, and 0.075 μg/m^3 for PM2.5, were detected, but during the second plume maximum concentrations of 0.225 μg/m^3 and 0.120 μg/m^3, for PM10 and PM2.5, respectively, were found.

Between the two episodes, Romania was exposed for two days to air masses coming from South-West, leading to an increase of the humidity.

Because of the total cloud cover, from the days of the April 19th and 20th, the particles trapped under the cloud layer were rapidly transported to the ground by dry deposition during the 19th of April. The precipitation event on April 20th (3.8 mm) caused a washout of ash particles trapped in the lower atmosphere (wet deposition).

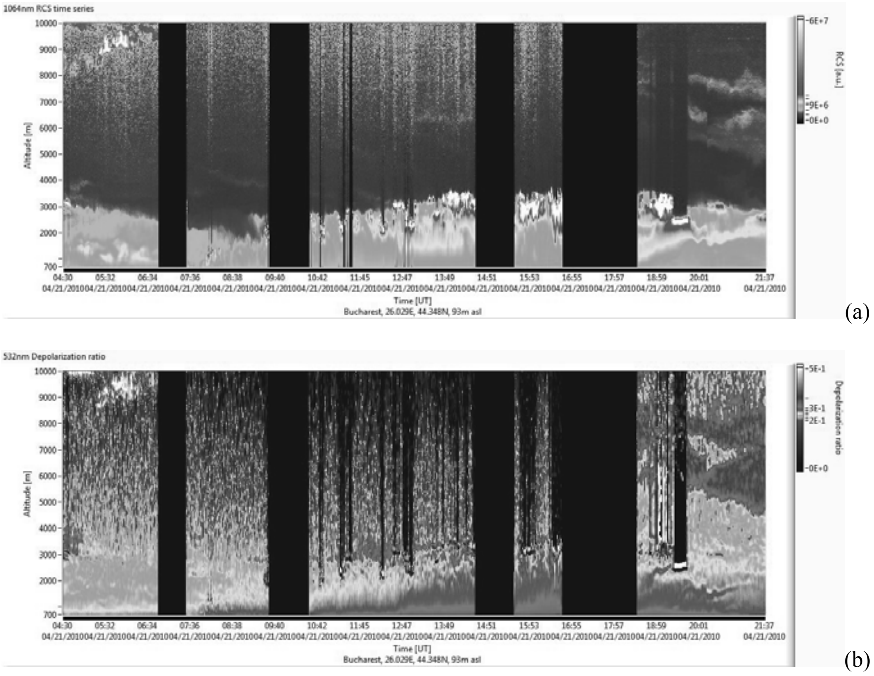


Fig. 4. Lidar images for April 21st: a) Range Corrected Signal temporal series and b) depolarisation ratio temporal series.

The two deposition processes significantly increased the ground level concentration and changed the size distribution of the particles. The size distribution derived form APS data, showed an increase of coarse mode of particles.

5. Conclusions

At Bucharest lidar station we have detected layers of ash plume transported over the Europe from Iceland during the Eyjafjallajokull volcanic activities. Due to the long distance from the source and transformation processes along the way, we indentified low concentrations of volcanic ash.

Dispersion modelled data from the Rhenish Institute for Environmental Research (University of Koln) are in good agreement with lidar and aerodynamic particle sizer spectrometer data.

Further analysis have to be made in order to characterize optical and microphysical properties of particles, as well as their possible mixing with local aerosols.

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